ECOLOGY

Project title:	**The Ecological Relationship Between a Rocky Mountain Threatened Species and a Great Plains Agricultural Pest**
Principal investigator:	Dr. Peter F. Brussard
Phone number:	775-784-1360
Email:	*brussard@biodiversity.unr.edu*
Address:	University of Nevada, Reno Biology Department 314 Reno, NV 89557
Additional investigators:	Hillary Lindsay-Robison

Objective: 1) To determine where army cutworm moths (*Euxoa auxiliaris*) (ACMs) originate. Pressures on ACM subpopulations, either natural (e.g., weather patterns) or human-caused (e.g., pesticides), may affect moth recruitment and the number of adults reaching high elevation sites where they are a critical food source for the threatened grizzly bear (*Ursus arctos horribilis*). 2) To determine if ACMs harbor agricultural pesticide residues in their tissues. Resulting pesticide magnification in grizzly bears that forage heavily on moths may have detrimental physiological or developmental side effects. 3) To elucidate the effects of weather on ACM migration from Great Plains agricultural areas to ACM aggregation sites in the Rocky Mountains. 4) To determine whether ACMs from different Great Plains origins are interbreeding in high elevation sites prior to their return to agricultural areas. If ACM subpopulations do not interbreed, unfavorable conditions in specific Great Plains areas may impact moth numbers in high elevation.

Findings: After completion of field work, data will analyzed, written in a Ph.D. thesis, and manuscript(s) submitted to peer-reviewed journals in 2002.

Project title: **Carnivore Detection Survey**

Principal investigator: Dr. Robert Crabtree
Phone number: 406-587-7758
Email: *yes@yellowstone.org*
Address: Yellowstone Ecosystem Studies
P.O. Box 6640
Bozeman, MT 59771

Additional investigators: M. Miller, D. Bopp

Objective: 1) Assess several methods to inventory and monitor medium-sized carnivores: weasel, otter, wolverine, marten, fisher, lynx, bobcat, mountain lion, fox, coyote, and gray wolf. 2) Examine various habitat and landscape characteristics related to their presence/absence. 3) Conduct presence/absence surveys in Yellowstone National Park and surrounding wilderness areas.

Findings: With the notable exception of three decades of research on grizzly bears, and more recent studies on mountain lions, pine marten, and coyotes, we know very little about Yellowstone's mammalian carnivores. Members of the order *Carnivora* are typically secretive, nocturnal, and exist at low population densities. In many cases, we do not even have reliable methods to determine presence, let alone estimates of abundance and other important demographic parameters. During the winters of 1990 through 1997 we conducted detection surveys and evaluated three methods: hair snares, remote camera stations, and snow track transects. Their utility as estimates of presence, distribution, and abundance were evaluated, as well as their cost, maintenance, reliability, precision, and bias. Responses to hair snares and camera stations were variable locally and between years. Hair snares have the exceptional advantage of providing DNA and potentially identifying individuals, but have the disadvantage of relatively high maintenance and cost, and they provided unreliable results from the analysis of hair characteristics. Camera stations, like hair snares, performed well in adverse weather and can identify individuals, but suffer from avoidance bias by several resident species. Camera stations were costly in terms of expense and maintenance. Snow track transects identified four species not detected by other methods and were simple, low cost, and low maintenance. They provide precise habitat information, whereas camera stations and hair snares are baited with food and scent lures, which bias results concerning habitat use. Snow track transects allow researchers coverage of large areas and habitat types and can provide valuable information if scats are found and if DNA is successfully extracted. The reliability of species identification from snow track transects is a major disadvantage due to poor climatic conditions and the similarity of many species' track characteristics. Although the specifics of objectives and logistics should dictate use of these methods, we suggest a variable combination of all three methods for determining presence and distribution. All methods have significant problems, especially when inferring abundance. Determining relative habitat use from snow track transects proved reliable and matched that known from previous studies. A manuscript was prepared on the evaluation of these three detection methods for medium-sized carnivores.

Project title: **Landscape Use by Elk During Winter on Yellowstone's Northern Range**

Principal investigator: Dr. Robert Crabtree
Phone number: See previous entry

Additional investigators: P. Moorcroft, Kirk Johnson, Phil Farnes, Mark Lewis

Objective: The objectives of this study were to document winter patterns of landscape use by Yellowstone northern range elk, measure elk feeding activity (as indexed by number of feeding craters), quantify snowpack characteristics, and examine how these and other landscape and habitat features influence elk foraging locations. How does snow affect the distibution of elk during winter on Yellowstone's Northern Range? What other factors, such as winter temperature, forage, and predator/ prey density, are affecting their distribution?

Findings: We measured site and snowpack characteristics, elk (*Cervus elaphus*) feeding crater densities and morphometry, and elk numbers in the Lamar River valley and the Blacktail Plateau on the northern range of Yellowstone National Park. We conducted the study over three winters, 1992-93 to 1994-95, but the main sampling effort occurred over four monthly sample periods in year one. Snow depth, snow water equivalent (SWE) and snow resistance to horizontal movement and vertical penetration all increased steadily over the winter. The mean (SD) feeding crater diameter and depth was 118 (37) cm and 34 (11) cm, respectively, and both were positively correlated with snow depth. The mean (SD) crater volume was 385 (321) liters, and the mean (SD) mass of snow excavated from a crater was 82 (72) kg. Non-woody plants (grasses, sedges and forbs) were the primary browse item in 90% of the craters. The highest aerial elk counts were observed in early- to mid-January, and counts declined substantially and steadily after January 29. At this time, mean snow depth was about 50 cm and mean SWE was about 12 cm. The mean number of new craters on a plot showed a significant, negative association with snow depth, SWE, and booted-foot sinking depth. We used the sum of craters on a plot across all four sample periods as an index of winter-long feeding activity. Elevation and habitat type were the best site characteristics for differentiating plots in regard to winter-long use. Summed craters were negatively associated with elevation, and the habitat type with the highest summed craters was tufted hairgrass/ sedge. Only about 5% of plots that had craters had aerial crater coverage in excess of 14%, with a maximum of 23% coverage, suggesting that snow disturbance associated with cratering activity may inhibit elk foraging.

Project title: **Ecology and Distribution of Red Fox (*Vulpes vulpes*) in Northern Yellowstone**

Principal investigator: Dr. Robert Crabtree
Phone number: See previous entry

Additional investigators: Robert Fuhrmann, Brad Swanson

Objective: 1) Determine habitat use of northern Yellowstone's red fox. 2) Examine the genetic variability of red fox subpopulations according to three elevational zones.

Findings: The distribution, morphology, and habitat use of red fox was examined in the northern Yellowstone ecosystem. Morphological and genetic samples were collected on live-captured and dead foxes to identify the presence and distribution of potential red fox subspecies across an elevational gradient. Examination of 22 red foxes indicated shorter tail length above 7,200 feet. Other parameters indicated trends of beneficial adaptations to climatically harsh environments at high elevations. At elevations above 7,200 feet, there was significantly higher frequency of a light gray coat color morph. Genetic analysis indicated that foxes above 7,200 feet were genetically isolated from lower elevations yet no geographic barrier exists. Habitat use was evaluated by snow-tracking fox using GPS and GIS technologies. Foxes were distributed across the study area in a wide range of forest cover types. Results show that red fox prefer forested and forest-edge habitats. Foxes significantly selected habitats that were less than 25 meters from an ecotone (structural edge). They preferred mesic sedge meadows and spruce-fir habitats at low angle slopes with a wide range in aspect. Lower elevational populations on the northern range were less specific in their selection of habitats and foraged mostly in mesic meadows and sagebrush. Above 7,200 feet, foxes preferred spruce-fir forests and foraged in mesic meadows and in spruce-fir and old-aged lodgepole forests. Clearly the mountain red fox that inhabits northern Yellowstone should be classified as a forest carnivore and is quite possibly a new subspecies of mountain fox, indigenous to North America. Further analysis and preparation of manuscripts will occur in 2000.

Project title: **Effects of 1988 Fires on Ecology of Coyotes in Yellowstone National Park: Baseline Succeeding Wolf Recovery**

Principal investigator: Dr. Robert Crabtree
Phone number: See previous entry

Additional investigators: J. Sheldon, C. Wilmers, A. Switalski, D. Bopp

Objective: Document long-term effects of the 1988 fires on the population dynamics and behavioral ecology of coyotes. Document the impacts of wolf restoration on coyote population and behavioral ecology, including the effects on coyote prey and competitor species. Continue long-term monitoring of coyote populations by adherence to those objectives listed in previous reports and peer-reviewed publications.

Findings: This project is beginning year 11 and is in the phase II: wolf-colonization period. A variety of significant behavioral and demographic effects of wolves on coyotes have occurred since the release of wolves in 1995. The effect of fires on coyotes directly continues to be insignificant, however indirect effects on the small-mammal prey base community continue. Forty-five resident adult coyotes occupy the Lamar Valley study area. This continues a well-established trend of an approximate 50% reduction compared to pre-wolf numbers. Almost complete extirpation of coyotes exists in the core area of the Druid wolf pack. Neonatal pup survival remains high (70 to 80%) but fall mortality (mostly due to wolves) was the highest ever recorded since the beginning of the study. We observed wolves killing coyotes in nine instances this year. Wolves raided coyote dens in at least eight instances. The first documentation of wolves killing and consuming a coyote pup occurred this year. Other behavioral impacts are still occurring: relegation of coyote dens to low wolf-use areas, high turnover of alpha pairs due to mortality, shifting territoriality, and low pack size. A functional increase in coyote scavenging (and other scavengers: eagles, ravens, bears) has occurred in response to the availability of wolf carcasses.

Project title: **Yellowstone Watersheds Initiative**

Principal investigator: Dr. Robert Crabtree
Phone number: See previous entry

Additional investigators: G. Terrie, J. Spruce, W. Minshall, R. Gresswell, G. Meyer, A. Marcus, J. Varley

Objective: Due to “funnel effects,” streams, riparian, and wetland areas are the accumulation zones of environmental disturbances occurring throughout their watersheds. For example, they are profoundly affected by eroded sediments from disturbances such as logging operations, forest fires, mining, recreation, and grazing. These disturbances introduce significant changes in stream sediment loads, stream morphology, and riparian vegetation. Because of funnel effects, stream and riparian areas are among the most sensitive indicators of large-scale environmental change. This general research initiative allows Yellowstone Ecosystem Studies to: 1) assist Yellowstone National Park with the monitoring of fish populations, stream characteristics, watershed impacts, and riparian and wetland assessments; 2) examine the effects of fire, exotics, mining activities, and other human impacts on stream, riparian, and wetland ecology; and 3) conduct data collection and analysis and prepare manuscripts.

Findings: This general initiative was primarily involved with the collection of multi-sensor data of stream, riparian, and wetland habitats in 1999. Extensive data were collected: 1) 14 band ATLAS (including 6 thermal bands); 2) 0.7 meter 4-band (digital); 3) 12-band AIRSAR (C, L, and P bands); 4) RadarSat (C-band); and 5) double x-band IFSARE. These data sets will provide the basis for the development of a remote-sensing approach to inventory and monitoring, as well as provide the basis for the development of indicators that reflect the ecological integrity of the associated watersheds. Streams and riparian areas have been relatively ignored by remote sensing researchers. This is primarily because the relatively low spatial and spectral resolution of traditional remote sensing data has not been conducive to successful analysis of these vital ecological lifelines. The corpus of scientific literature on remote sensing of streams is lean. Previous research suggests that finer-scale imaging with multiple sensors can achieve a major breakthrough in remote sensing of stream, riparian, and wetland areas for both scientific and commercial applications. Year 2000 efforts will focus on analysis and classification utilizing the multi-sensors listed above.

Project title: **Validation of High Resolution Hyperspectral Data for Stream and Riparian Habitat Analysis**

Principal investigator: Dr. Robert Crabtree
Phone number: See previous entry

Additional investigators: J. Boardman, A. Marcus, R. Aspinall, D. Despain, W. Minshall, K. Halligan, J. Norland, J. Richardson, L. Foss

Objective: The objectives of this hyperspectral EOCAP project are twofold. First, the project seeks to test the application of airborne hyperspectral imagery to riparian and in-stream ecological and environmental studies and monitoring. Secondly, using experience gleaned from these application tests, we are defining the unique and common requirements of hyperspectral data for operational commercial and scientific uses in the area of stream and habitat analysis. The results we are creating fall into these two broad categories: specific stream study application results and more general conclusions about commercial hyperspectral data requirements. We are documenting which specific stream ecology variables can best be measured from airborne hyperspectral sensors, and which stream parameters are not amenable to hyperspectral determination. Through acquisition of the field and airborne data, development of experimental protocols, analysis, and processing of the hyperspectral data and documentation of the results, we are building the case for stream and riparian studies using hyperspectral data. Furthermore we are discovering, often through the process of trial and error, numerous critical gaps and deficiencies that exist in current systems that hinder the commercialization of hyperspectral data for riparian studies.

Findings: In 1999 a variety of hyperspectral data sets were collected or obtained: 1 meter, 5 meter, and 10 meter Probe-1 (128 channels) and 2 meter and 17 meter AVIRIS data (224 channels). Extensive ground-truth data were collected along the Soda Butte and Cache Creek study sites. Six main classes of ecological parameters that we seek to study and classify are: 1) stream morphological units; 2) steam depth and flow regime; 3) substrate particle size; 4) in-stream algae chlorophyll levels; 5) woody debris; 6) heavy metals and associated mine tailings in fluvial sediments; and 7) riparian vegetation community mapping including individual species identification of willow, sedge, cottonwood, aspen, upland grasses, rushes, alder, sagebrush, and conifer species.

These six main classes of variables span the range from relatively easy to extremely difficult, in terms of hyperspectral measurement. Each ecological variable has its own degree of hyperspectral "leverage", or observability in the hyperspectral data. Furthermore, key issues such as spatial and spectral resolution, noise level, geometric fidelity, geopositioning accuracy, and timeliness of data delivery and processing affect each specific application differently. Using multiple spatial and spectral resolutions, and multitemporal data sets, we are investigating and documenting the complex interplay between instrument and data parameters and the usefulness and accuracy of the derived ecological products.

While spectral contrasts exist among classes and species of vegetation, and even exist among subclasses of a single type, they are subtle and change throughout the growing season. Unlike the small spatial scale and rapidly time-varying nature of the in-stream parameters, the riparian vegetation is distributed in broader units that generally persist from one season to the next. Successful mapping of these plant species rests heavily on correlation of field spectrometry with airborne data. This particular application lends itself to a multitemporal approach, leveraging the different spectral "trajectories" of the plant communities throughout the growing season. Initial investigations of the airborne data show tremendous spectral diversity in the riparian vegetation. Empirical spectral analysis indicates that more than a dozen spectrally unique vegetation classes can be mapped. Current efforts involve matching field mapping with the aircraft data results.

Throughout our EOCAP project we are focusing on our dual hyperspectral objectives: developing convincing case study demonstrations of the hyperspectral measurement of important stream and riparian ecology parameters and documenting and developing the common and unique requirements of operational systems to perform these studies in the future. Specifically, we are collecting a laundry list of needs and requirements for commercial systems for hyperspectral stream studies. This list documents specific spatial, spectral, and radiometric design requirements. In addition, we are addressing the more mundane, yet critical, aspects of operational acquisition and application including the timely delivery of data and products and its long-term use and archiving. Our initial results from our first field season are very encouraging and productive, both in terms of the development of tantalizing case studies and the frustration involved with finding and documenting technology gaps and shortcomings.

Project title: **Specificity of Ectomycorrhizal Symbioses**

Principal investigator: Dr. Ken Cullings
Phone number: 650-604-2773
Email: *kcullings@mail.arc.nasa.gov*
Address: NASA-Ames Research Center
MS 239-4
Moffett Field, CA 94035-1000

Additional investigators: Sharon Cullings, J.R. Blair, Debie Kinsey, Robert Douglas

Objective: 1) To determine whether specificity exists in the ectomycorrhizal community. 2) To determine effects of disturbance and chemical gradients on ectomycorrhizal community structure and specificity patterns.

Findings: 1) Defoliation has a significant effect on ectomycorrhizal community composition. 2) There is no significant difference in ectomycorrhizal community structure between wet and dry periods of a single growing season, but there is between winter and summer. 3) Litter addition has a significant effect on mycorrhizal root distribution and on fruiting. Analysis of changes to species composition is in progress.

Project title: **Habitat Requirements and Evolution of *Agrostis rossiae* Vasey, a Species Endemic to Yellowstone National Park**

Principal investigator: Dr. Steven Darwin
Phone number: 504-865-5191
Email: *mtercek@mailhost.tcs.tulane.edu*
Address: Department of Ecology, Evolution, and Organismal Biology
310 Dinwiddie Hall
Tulane University
New Orleans, LA

Additional investigators: Michael Tercek

Objective: *Agrostis rossiae* is a grass endemic to thermal areas in the Old Faithful-Shoshone area. Populations are small and isolated, but are usually parapatrically distributed with respect to a morphologically similar, cosmopolitan congener, *Agrostis scabra*. Both species are highly plastic and converge morphologically in some populations. The objectives of this study are: 1) Determine which ecological factors are responsible for the endemism of *A. rossiae*. 2) Determine the historical relationship between *A. rossiae* and *A. scabra*. A phylogenetic study based on molecular and morphological data will verify that *A. rossiae* is monophyletic and test the hypothesis that it is the sister taxon of *A. scabra*. 3) Use population genetic models, common garden, and greenhouse experiments to explain the geographic distribution of *Agrostis rossiae* and *Agrostis scabra* populations in terms of gene flow and natural selection. 4) Investigate plant speciation paradigms. Because of abrupt variations in soil temperature and other edaphic factors, Yellowstone's thermal communities are ideal locations for testing speciation theory. The spatial scale at which divergent selection pressures appear to act is well within the range at which cross-pollination and seed dispersal occurs. It is suspected that *A. rossiae* has been sympatrically derived from *A. scabra*.

Findings: During the summer of 1999, we cooperated with Park Service personnel in an effort to GPS map all known *A. rossiae* populations. We collected specimens of *Agrostis rossiae* and *Agrostis scabra* for genetic analysis. Soil temperature data were collected with data loggers located on transects that traverse the boundary between the two species. Soil samples and *Agrostis* seeds were collected. Common garden experiments were initiated. Genetic analysis and greenhouse experiments are in progress. Field work will continue in summer 2000. All plant specimens collected are housed in the Tulane University herbarium.

Project title: **Assessing Ecosystem Integrity: An Approach Modeling Energy Flow**

Principal investigator: Dr. Walter Duffy
Phone number: 707-826-3268
Email: *wgd7001@axe.humboldt.edu*
Address: California Cooperative Fish Research Unit
Humboldt State University
Arcata, CA 95521

Additional investigators: Diane E. Ashton, Peggy Wilzbach, Ken Cummins

Objective: 1) To compare wetland aquatic invertebrate production estimates and P/B ratios from stressed and non-stressed ecosystems; and 2) to evaluate the use of energy flow/flux in monitoring ecosystem integrity.

Findings: We have identified 187 taxa in samples from YNP wetlands. Of these, 131 (70%) had not previously been reported from the park. Community structure of aquatic invertebrates in wetlands was influenced by duration of flooding and presence of salamander larvae. A book chapter detailing these findings was published in 1999 and copies provided to the YNP Center for Resources. Collections are housed at the California Cooperative Fish Research Unit, Humboldt State University.

Project title: **The Sustainability of Grazing Ecosystems**

Principal investigator: Dr. Douglas Frank
Phone number: 315-443-4529
Email: *dafrank@mailbox.syr.edu*
Address: Biological Research Labs
Syracuse University
Syracuse, NY 13244-1220

Additional investigators: Peter Groffman

Objective: To determine the effects of large herbivores on plant production and nitrogen cycling in Yellowstone National Park.

Findings: Grazers increased aboveground production by an average of 20% at ten study sites that varied widely in elevation, soil properties, species diversity, and plant production. Below-ground production of grazed and fenced, ungrazed grassland is currently being assessed from monthly images captured from minirhizotron tubes. A growth chamber experiment on a common Yellowstone grass indicated that clipping stimulated root exudation (carbon), rhizospheric microbial biomass, net N availability, and plant tissue N content. These results suggest that this species is capable of "farming" its rhizospheric microbial population to accelerate N availability and uptake. Roots of grasses growing inside and outside long-term winter range exclosures were stained to determine the intensity of mycorrhizal colonization. We found that ungulates had no effect on mycorrhizal infection rates at two time-points (early-May, mid-June) during the 1999 growing season. All plant collections will be donated to the Yellowstone herbarium upon completion of the project.

Project title: **Climatic Variation in the Greater Yellowstone Ecosystem: Evaluating the Evidence for Decade to Centennial Variability in Climate**

Principal investigator: Dr. Lisa Graumlich
Phone number: 406-994-5320
Email: *lisa@montana.edu*
Address: Mountain Research Center
Montana State University
Bozeman, Montana 59717-3490

Additional investigators: John King, Jeremy Littell

Objective: Develop a multi-species network of tree-ring data within the Greater Yellowstone Ecosystem to: 1) document and explain spatial and temporal climatic variability; 2) predict vegetation response to climate; and 3) increase scientific understanding of the processes and factors controlling forest dynamics.

Findings: Tree-ring collections made during 1999 yielded six 1000± year records and one 2000± year record of tree growth. Preliminary analyses demonstrate that the Greater Yellowstone Ecosystem tree-ring chronologies contain strong precipitation signals at both high and low frequencies. These results combined with a spectral analysis suggest that multi-decadal north Pacific atmosphere-ocean circulation features have been an important driver of regional climate over the past two millennia. Low frequency features in these chronologies provide preliminary evidence for persistent droughts that differ in timing compared to California drought reconstructions. As such, these data offer an important tool for understanding the spatial extent of severe droughts in western North America.

Projected research for 2000 includes: 1) 1000± year reconstructions of temperature and precipitation in the Northern Rockies; and 2) characterization of the relationships between multi-decadal climate patterns and ocean-atmospheric interactions.

Project title:	**Cougar-Wolf Interactions in Yellowstone National Park: Competition, Demographics, and Spatial Relationships**

Principal investigator:	Dr. Maurice Hornocker
Phone number:	208-885-6871
Email:	*hwi@uidaho.edu*
Address:	Hornocker Wildlife Institute P.O. Box 3246 University of Idaho Moscow, ID 83843
Additional investigators:	Toni K. Ruth, Howard Quigley

Objective: 1) Document interspecific killing and the characteristics of the cougar population, including population size, survival, cause-specific mortality and natality, and compare with analogous estimates made prior to wolf restoration (Phase I data; Murphy 1998). 2.) Assess competition, habitat, and food use characteristics of the two species. 3) Quantify spatial interactions between cougars and wolves. 4) Assess the effects of cougars on elk and mule deer populations as influenced by the presence of wolves. 5) Communicate research findings to state and federal agencies and the general public through annual technical reports, research updates, and presentations.

Findings: Hornocker Wildlife Institute (HWI) personnel captured and radio-collared 16 cougars in and adjacent to areas used by three wolf packs on the northern Yellowstone study area (NYSA), Montana and Wyoming. A sample of 3 to 10 radio-collared wolves was maintained within each wolf pack by the Yellowstone Wolf Project. Researchers associated with both HWI and Yellowstone National Park conducted aerial and ground monitoring of radio-instrumented animals. HWI field crews searched 1,589 km of track transects to conduct winter cougar sign surveys and provide an estimate of cougar population size. A minimum of 21 adult and sub-adult cougars were present on the NYSA during the 1998-1999 winter season. An additional 3,113.6 km were traveled by foot or snowshoe to conduct ground radio tracking, predation sequences, document prey kills, and search cougar location sites during the report period.

Two adult female cougars produced litters of three offspring (female F47) and two male offspring (female F105). Eight of 10 kittens associating with four separate family groups were radio-marked and monitored. An unmarked male (or males) killed two sub-adult male cougars in early spring, 1999. Both sub-adult males appeared to be establishing residency (scrapes and localization), but may have been potential dispersers.

Seventy-two positive and probable cougar kills were documented. Prey included 55 elk, 7 mule deer, 1 bighorn sheep, 4 coyotes, 4 porcupines, and 1 red squirrel. Three predation sequences of 26 to 35 consecutive days resulted in a mean predation rate of 8.4 days per ungulate kill for the 3 cougars sampled. Approximately 187 ground and 98 aerial locations were obtained on cougars. Five flights were coordinated with Wolf Project personnel to obtain simultaneous locations on cougars and wolves for spatial-temporal analysis. A resource selection protocol for collection of site-specific habitat and prey information is under development.

Project title: **'96 Field Course - Forest Ecology and Geology of the Yellowstone Country**

Principal investigator: Dr. Karen Kuers
Phone number: 931-598-1421
Email: *kkuers@sewanee.edu*
Address: University of the South
Department of Forestry and Geology
735 University Ave
Sewanee, TN 37383-1000

Additional investigators: Martin Knoll

Objective: The major forestry objectives are to 1) identify stands representative of the various forest habitat and cover types described by Despain (1990); 2) establish permanent plots within each stand; 3) develop a database of stand characteristics such as tree species composition, height, age, and understory composition for each plot; and 4) establish transects to investigate species gradients in relationship to thermal features. The plots will be used to illustrate the concept of habitat typing as applied to Yellowstone forests. The primary geology objectives are to 1) study temperature and pH gradients in Yellowstone Lake and representative hot springs; 2) characterize thermal features representative of different regions of the park; and 3) identify rock types characteristic of the major volcanic episodes in Yellowstone. The field course is taught during alternate years.

Findings: Several stands representing different lodgepole pine or Douglas-fir cover types were identified and dominant tree heights, diameters, and ages were recorded during the three-week field course in the summer of 1999. Sites visited in 1995 or 1997 were revisited and one new site was established. Vascular plant species lists were recorded along the Yellowstone Canyon rim, Pebble-Creek Trail, Hoodoos Trail, and the Black Canyon Trail and compared to previous years. GPS locations were recorded for the study sites to facilitate site maps. A temperature depth profile was recorded for Yellowstone Lake in the vicinity of Stevenson Island. Temperature and pH was compared along the stream and within a series of hot springs located near White Creek and near the upper terrace of Mammoth Hot Springs. The next summer field course is scheduled for August 2001. Sites visited on previous trips will be revisited, data updated, and new sites will be established.

Project title: **Study of the Effects of the 1988 Wildfires on Yellowstone Stream Ecosystems**

Principal investigator: Dr. G. Wayne Minshall
Phone number: 208-236-2236
Email: *minswayn@isu.edu*
Address: Department of Biological Sciences
Idaho State University
Pocatello, ID 83209-8007

Additional investigators: A. Marcus

Objective: The overall objective of this study is to separate the early from the delayed effects of wildfire on stream ecosystems in Yellowstone National Park. Specific goals include documenting changes in stream habitat and biota each successive year following the 1988 wildfires, thus providing a basis for predicting and evaluating subsequent long-term changes. Few streams greater in than size than 4th order were substantially affected by the fires, and this study focuses on streams of 1st through 4th order. To increase the breadth and precision of the study and to provide more general conclusions, each size class (order) is represented by four to five streams, as well as by at least one reference stream that was not affected by the fires.

Since 1993, the research has been limited to streams in the Cache Creek drainage basin, due to financial constraints. This has meant elimination from the study design of reference sites (except for Amphitheater) and much of the sampling replication. Nevertheless, samples from one of the most intensively burned watersheds (Cache) are being collected each year (other than 1996) through cooperation with Yellowstone Ecosystem Studies. However, in 1998 sampling of all the original sites was completed.

Findings: Although the effects of fire were evident in early years of this study, the streams could be characterized as being largely on a "fast recovery track." However 1991 and 1994 were marked by runoff events that caused substantial alteration of physical habitat in the streams in burned watersheds, particularly those in moderate to steep gradients. Even greater physical alterations occurred in 1995 (and probably in 1996) and were evident again in 1997. The dramatic changes in 1995-1997 are associated with a general increase in precipitation in those years. Disturbances such as these are reflected in declines in the biotic components of the stream and serve as important "resets" in the recovery process. However, as was evident from examination of one of our reference streams (Amphitheater) in 1997, some of those differences are more a response to a change in annual weather conditions than to fire per se. The analyses conducted to date indicate a substantial change in channel morphology (wider, more shallow) in the larger (3rd and 4th order) burned streams than in a similar size reference stream during the eleven years since the fire. In contrast, initial changes (narrower, deeper) in the smaller (1st and 2nd order) burned streams than in their reference streams have dissipated during that time. Periphyton (attached algae) and benthic organic matter did not show any consistent difference between burned and unburned streams but several aspects of macroinvertebrate community structure did. In general, densities were higher and percent Ephemeroptera-Plecoptera-Trichoptera (%EPT, a measure particularly sensitive to disturbance) taxa were lower (=greater impact) in the burned streams than in the reference streams. These changes were accompanied by an increase in the proportion of smaller, more vagile taxa, suggesting a shift in community structure from K- to r-strategists. However, these differences did not exist for taxa richness or biomass, indicating that metabolic compensation accompanied the change in community structure. The results obtained thus far indicate that there still are discernable impacts in the burned streams eleven years after disturbance by wildfire.

Project title: **The Influence of Soil on Whitebark Pine (*Pinus albicaulis*) Cone Prodcution in the Greater Yellowstone Ecosystem**

Principal investigator: Adam Morrill
Phone number: 406-582-1392
Email: *amorrill523@yahoo.com*
Address: 1104 S. Montana Ave. #C11
Bozeman, MT 59715

Additional investigators: Kathy Hansen, Bill Locke, Ward McCaughey, Chuck Schwartz

Objective: To determine to what extent the measured soil properties affect whitebark pine cone production.

Findings: This research examined the relationships between whitebark pine (*Pinus albicaulis*) cone production and soil properties and foliar nutrient levels. Cone count data were collected by the Interagency Grizzly Bear Study Team from plots across the Greater Yellowstone Ecosystem (1980-1999). The data used in this study came from eight of those plots (78 trees) and covered the years of 1989-1997. Soil properties measured included: electrical conductivity (EC), pH, percent coarse material, texture (percent sand, silt and clay), and percent organic matter and depth. Foliar nutrient levels were determined for the following nutrients: boron, calcium, copper, iron, potassium, magnesium, manganese, molybdenum, nitrogen, phosphorus, sulfur and zinc. These variables were regressed against cone production to determine their influence and significance. EC and pH both had significant positive correlations with cone production, and percent coarse material had a significant negative correlation with cone production. EC is a measure of the concentration of ions in solution, and in whitebark pine environments it can be used as an approximation of the amount of available nutrients. When soil pH levels approach neutral, more nutrients necessary to plants become available. Percent coarse material limits the amount of surface area on which nutrients or water may be held, and thus limits productivity. All other variables had no significant relationships with cone production. A multiple regression model using EC and pH significantly explained 38% of the variation in cone production. Percent coarse material was insignificant in the model because of its covariance with EC and pH, suggesting that it affected soil chemistry rather than water availability. A second multiple regression model, which used crown volume and EC, significantly explained 59% of the variation in cone production. Soil pH was not used because of its correlation with EC, and because EC had more predictive power. The information gained from this study could be used to assist in site selection for planting of whitebark pine and in developing other management strategies that increase whitebark pine cone production and provide better wildlife habitat.

Project title: **Statistical Methods for Assessing Complex Ecosystem Processes and Population Dynamics: A Case Study of the Yellowstone and Teton National Parks Shiras Moose**

Principal investigator: Dr. Bruce Pugesek
Phone number: 406-994-6144
Email: *bpugesek@montana.edu*
Address: USGS-BRD, Northern Rocky Mountain Research Center
1648 S. 7th, MSU Forest Science Lab
Bozeman, MT 59717

Objective: Houston described a complex process involving both environmental and population level variables that he believed were the ultimate determinants of moose population size. The objective of this study is to develop a statistical method capable of both testing and parameterizing the complex process envisioned by Houston. Structural equation modeling methods will be employed to construct a statistical model for this purpose.

Findings: This research presents an example of how SEM could be used to test a classic theoretical model of population dynamics of the Shiras Moose. A longitudinal model is developed in which population density is measured in two waves. The change in population density between the two periods of measure is modeled in relation to a complex set of interrelationships among environmental and population level variables. Included in the model are examples of composite variables and non-zero fixed parameters. Analysis of a simulated data set demonstrates the procedures of a typical SEM study in which analysis begins first with the analysis of a measurement model, and proceeds with a series of exploratory and confirmatory analyses. The use and pitfalls of fit statistics, t-values, modification indices, and Q-Q plots as diagnostic tools are demonstrated. Two types of estimates, maximum likelihood covariance estimates and standardized solution estimates, are contrasted. Examples of the calculation of total effects from direct and indirect effects are presented. Results demonstrate a significant potential for using SEM data analysis and simulation capabilities to develop expert systems and ecological models.

Project title: **Aspen Regeneration in Northern Yellowstone National Park**

Principal investigator: Dr. William J. Ripple
Phone number: 541-737-3056
Email: *Bill.Ripple@orst.edu*
Address: Department of Forest Resources
280 Peavy Hall
Oregon State University
Corvallis, OR 97331

Additional investigators: Eric J. Larsen, Roy Renkin, Douglas Smith

Objective: Based on trophic cascades theory, the objective of this research is to gather data on how wolves may modify the spatial pattern and intensity of elk browsing on northern range aspen. Using YNP radio telemetry data on wolves and a fixed kernal estimate, we delineated polygons representing high-use winter activity areas of three of YNP's northern range wolf packs. These polygons were then overlain onto our northern range aspen inventory, and aspen were grouped into two categories: those stands containing a high density of wolf telemetry locations (inside of 50% fixed kernal estimate) and those lying in areas of lower densities of telemetry locations (outside of 75% fixed kernal estimate). A random selection of aspen stands was made from each of the two groups. Transects were established in the chosen aspen stands and data collected to study the following objectives: 1) to determine if there are significant differences in aspen sucker heights and elk densities (determined by elk pellet counts) between stands in areas of high winter use by wolves and in areas of lower use; 2) To establish permanent aspen plots and provide baseline data to study the long term influence of wolves on structuring aspen communities in the Yellowstone ecosystem.

Findings: During 1999, belt transects were established and field data collected from 113 plots on YNP's northern range. Differentially corrected GPS readings were taken for each sampled aspen stand. Each transect was 1x20 meters, starting from a random position on the edge of each stand. Heights of all aspen suckers within the transect were recorded and were classified as browsed, unbrowsed, or dead (based on the previous year's leader). The diameter at breast height of all overstory trees in the transect were recorded. A count of elk pellet groups was conducted in each transect. The generalized habitat type of each aspen stand was recorded using the categories of mesic upland steppe, xeric upland steppe, wet meadow, riparian, or scree/miscellaneous. The aspect, slope, elevation, topographic position, and recent fire history (burned/unburned) of each stand was recorded.

The data analysis is in the preliminary stages. To control for differences due to habitat type and site quality, the data will be separated into groups for analysis. Our research plan includes revisiting the plots every three years to establish a long-term record of changes to aspen communities on the northern range and the possible effects of predation on changing elk browsing patterns and behavior.

Project title: **Causes and Consequences of Alternative Successional Trajectories Following the 1988 Yellowstone Fires**

Principal investigator: Dr. William Romme
Phone number: 970-247-7322
Email: *romme_w@grumpy.fortlewis.edu*
Address: Biology Department
Fort Lewis College
Durango, CO 81301

Additional investigators: Monica G. Turner, Gerald A. Tuskan, Dennis H. Knight

Objective: 1) Predict and map the early successional pathways of areas burned in 1988 on the basis of percent serotinous lodgepole pine trees, size of burned patch, and local severity of fire. 2) Map percentage of serotinous trees across the landscape. 3) Measure aboveground net primary productivity and leaf area index in stands representing different initial pathways of plant succession following the Yellowstone fires of 1988. 4) Re-sample plant cover and density in the permanent plots established in 1990 within nine different patches of 1988 crown fire.

Findings: 1) We obtained 1:30,000 color aerial photos of the entire park in August 1998. Approximately 10% of the area that burned in 1988 now supports very high-density stands of 10-year old lodgepole pine trees (greater than 50,000 stems/ha); 10% supports very low-density lodgepole pine (less than 100 stems/ha); and the remaining burned area has stands of intermediate tree density. 2) Initial sampling of percent serotiny indicated highest percentages at lower elevations in the west-central portion of YNP, and lowest percentages in high-elevation forests in the central and eastern portions of the park. 3) Aboveground net primary productivity (ANPP) and leaf area index (LAI) were measured in 1999 in 88 stands that had burned in 1988. These fundamental measures of ecosystem function varied with sapling density, ranging from 0.9 - 12.6 metricton/hectare/year (ANPP) and from 0.03 - 4.6 m^2/m^2 (LAI).

Project title: **Effects of Fire Size and Severity on Early Succession and Aspen Seedling Establishment**

Principal investigator: Dr. William Romme
Phone number: See previous entry

Additional investigators: Monica G. Turner, Gerald A. Tuskan, Dennis H. Knight

Objective: 1) Sample density and survival of aspen seedlings throughout the areas burned in 1988. 2) Determine experimentally the effects of ungulate browsing, plant-to-plant competition, micro-climate, and genetics on survival and growth of aspen seedlings. 3) Measure plant cover, density, and diversity in permanent plots established in 1990 throughout the areas burned in 1988. 4) Predict and map the early successional pathways of areas burned in 1988 on the basis of percent serotinous lodgepole pine trees, size of burned patch, and local severity of fire. 5) Map percentage of serotinous trees across the landscape. 6) Measure aboveground net primary productivity and leaf area index in stands representing different initial pathways of plant succession following the Yellowstone fires of 1988.

Findings: 1) Aspen seedlings are most abundant in burned forests of the western and west-central portions of Yellowstone NP, along the Madison and Firehole Rivers. 2) Experiments on the effects of browsing and competition are ongoing. So far the plants have shown relatively little response to protection from browsing or to removal of local competitors. 3) Trends in plant cover, density, and diversity that were measured from 1990-1993 generally continued through 1996. The permanent plots will be re-sampled in 2000. 4) We obtained high-resolution aerial photos of the entire park area in August 1998, and are using these photos to map areas that burned in 1988 and now exhibit high-density lodgepole pine, low-density lodgepole pine, or non-forest vegetation. 5) Initial sampling of percent serotiny indicated highest percentages in the west-central portion of Yellowstone NP. 6) Productivity and LAI will be sampled in 1999.

Project title: **Sagebrush Ecology and Ungulate Relationships**

Principal investigator: Dr. Carl Wambolt
Phone number: 406-994-5580
Email: *cwambolt@montana.edu*
Address: Montana State University
Animal & Range Sciences Department
P.O. Box 172900
Bozeman, MT 59717-2900

Additional investigators: Reyer Rens

Objective: 1) To determine the current status of the sagebrush-shrub community on the northern Yellowstone mule deer winter range. 2) Determine the importance of the sagebrush-shrub community to wintering mule deer and elk. 3) Describe the effect of human-caused and natural fire, including interactions with browsing, on sagebrush ecology on the northern Yellowstone winter range. 4) Determine what management techniques can be implemented to preserve or enhance mule deer and elk habitats associated with sagebrush-shrub communities.

Findings: Mule deer utilize the several sagebrush habitat types in the boundary line area as key wintering types. They use the four woody sagebrushes and three rabbitbrushes heavily as browse, although they display a decided preference among taxa on winter range. None of the sagebrushes have reestablished very well following burning as long ago as 19 years. The rabbitbrush taxa have responded to burning somewhat better, but heavy browsing has not allowed them to attain a very significant role in their respective habitats. Some mountain big sagebrush plants establish most years but some years are enormously more important for establishment of the taxon. Communities of older sagebrush plants are more productive than those of younger plants. Sagebrush production can be modeled using taxon and form class with great accuracy. Significant differences exist in the development of protected and browsed shrubs of big sagebrush habitat types. Preliminary information indicates that wildfires and ungulate browsing interact as determinants of sagebrush recovery. The actual degree of interaction varies among sites that differ in environmental conditions.

Project title: **Community Position and Pattern along a Continuous Thermal Gradient: Physical and Biological Constraints**

Principal investigator: Dr. Richard Wiegert
Phone number: 706-542-1661
Email: *Dick@Weigert.marsci.uga.edu*
Address: University of Georgia
Department of Marine Sciences
Athens, GA 30602

Objective: The objective of the current phase of the project is to follow the long-term dynamics of the organisms in thermal communities in the temperature range from 45° C down to ambient.

Findings: During the past year research activities at Yellowstone National Park included continued censuses of emerging adults of the dragonfly (*E. collocatus*) and whole system censuses of selected thermal communities located in West Thumb, Upper, Midway, and Lower Geyser basins and areas along the road from Madison Junction to Mammoth Hot Springs. I also spent a small amount of time searching other, more isolated thermal areas for thermal communities unusual in terms of either temperature/nutrients or animal/plant species. No additional sites were added last year. A paper on the comparative ecosystem work is nearing completion. In addition, during the past year I wrote a review of thermal biodiversity that is in press for the upcoming *Encyclopedia of Biodiversity* by Academic Press.

One objective of the current research is to compare long-term variability in the systems. A second objective is to explore the variability with the various classes of thermal community, i.e., hot (greater than 40° C), warm (less than 40° C) and, within this classification, the water chemistry, i.e., alkaline or acid.

The dragonfly census work is done in Gentian Stream, Serendipity Meadow just off of Firehole Lake Drive in the Lower Geyser Basin. I now have 20 years of total emergence counts and am trying to get temperature/precipitation data from the Old Faithful weather station to see if the large year-to-year variability in production of adults is related to weather. I have also begun to measure stream and local air temperatures with data loggers in place all year. Two papers on this work are started, but will require at least two-three more years of data.